Dressing the nucleon causally

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Concluding remarks

The main part of this thesis has been devoted to the development of the dressing procedure for the nucleon self-energy and for the πNN and γNN vertices. As the framework for the dressing procedure, we have chosen a Lorentz invariant, unitary and crossing symmetric K-matrix approach. Furthermore, causality constraints are invoked in the model as we employ dispersion relations to construct the form factors and self-energy functions with appropriate analyticity properties. We would like to conclude with a reflection on the role of general principles underlying our model for the dressed 2- and 3-point Green's functions.

We have stressed that off-shell form factors and self-energy functions should be calculated together with the scattering amplitude in the same framework. However, due to the representation-dependence of the off-shell Green's functions on the one hand and the representation-independence of the observables on the other, experiment cannot provide an unequivocal guideline for setting up a model to calculate the Green's functions. In these circumstances, additional constraints on such a model should come from basic principles of quantum field theory. The Lorentz invariant model of this thesis exploits constraints from unitarity and causality inasmuch as it is based on the use of cutting rules and dispersion relations whose proof rests on those principles.

Unitarity implies conservation of quantum mechanical probability, irrespective of the reaction mechanism. It lies at the basis of the cutting rules which we utilize to calculate the imaginary parts of the form factors and self-energy functions from the pole contributions to the loop integrals. Causality states that two events cannot affect each other if they happen outside each other's light cones, i.e. if an unphysical signal propagating faster than light is required to connect them. The tenet of causality is of a special significance for our approach. In particular, the analyticity properties of the half-off-shell form factors and self-energy functions, which are exploited in the dressing procedure through the use of dispersion relations, can be established only provided the interacting fields are causal.

The above argumentation can be regarded as justified only if the scattering amplitude constructed out of the resulting dressed Green's functions is consistent with experiment. We have shown that the model is capable of a good quantitative description of pion-nucleon scattering, pion photoproduction and Compton scattering at low and intermediate energies, even though the range of parameters is constrained by the dressing procedure. Particularly noteworthy is that, due to the implementation of causality constraints, we reproduce the cusp structure of the observables for Compton scattering. Also, the calculated nucleon polarizabilities are close to their measured values. The last two features were not possible to achieve in the traditional K-matrix approaches, where no dressing was taken into account.

Perhaps the most promising extension of the present approach is to apply the developed dressing technique to one-particle irreducible 4-point functions. This means treating $\pi\pi NN$, $\gamma\pi NN$ and $\gamma\gamma NN$ vertices dynamically, i.e. calculating the principal-value parts of the one-particle irreducible diagrams by applying dispersion relations to the corresponding pole parts generated through unitarization. Such a model would give a fuller account of the analyticity properties of the scattering amplitude. Another interesting line of development is an inclusion of nuclear medium effects in our model. This is important for studying the scattering of pions and photons from nuclei, where the constituent nucleons are bound and therefore can be far off the mass shell. We have done exploratory calculations which indicate that such an extension of the model is indeed possible.